Section 8
Payloads Overview

8.1 Introduction

The International Space Station (ISS) Payloads Overview lesson is designed to provide general information on types of research, major Payload components and overall utilization of the International Space Station. The first section of this lesson describes the types of research the ISS Program has planned for Station, identifies their potential benefits, and highlights some of ISS unique capabilities. The second section provides definitions of important ISS Payload components.

8.2 Objectives

After completing this lesson, the student should be able to

- Identify the types of research planned for ISS
- Identify the general characteristics of important Payload components

8.3 ISS Utilization

The purpose of the ISS is to provide a permanent manned laboratory for conducting science, research and technology development in space.

The principle advantages for conducting research on Station are the access to the microgravity environment, the unique vantage point provided by low Earth orbit, and the extended periods of time to perform the experiments. An additional advantage offered by the Station is the opportunity to repeat or modify the experiments based on current results.

8.4 ISS Types of Research

NASA sponsors research in the following six disciplines

- Life Sciences
- Microgravity Sciences
- Space Science
- Earth Science
- Commercial Product Development
- Engineering Research and Technology

8.4.1 Life Science

Life sciences research conducted on the ISS focuses on critical physiological issues that affect crew health and performance in long duration space flight. Research on the cardiovascular system, cardiopulmonary system and musculoskeletal system could lead to possible methods for treatments and prevention of numerous diseases and medical conditions experienced on Earth. The benefits expected from life sciences research include the improvement of medical treatments for diseases such as anemia, cancer, diabetes and osteoporosis.

Scientists will also study how plants and animals adjust to the absence of gravity. The study of plants may lead to improved plant growth systems and conservation of soil, water, and energy.

8.4.2 Microgravity Sciences

In a microgravity environment scientists will have a unique opportunity to study processes which are obscured by gravity on Earth (such as buoyancy-driven convection and sedimentation) and to test physical theories at levels of accuracy that are impossible on Earth. The ISS orbiting laboratory permits larger and longer duration experiments which allow more detailed observation. The specific disciplines of microgravity science which are studied aboard ISS include: materials science, combustion science, fluid physics, fundamental physics, and biotechnology. Some of the benefits which could result from microgravity research are

- Materials Science: better electronic devices and improved optical fibers for telecommunications
- Combustion Science: enhanced energy efficiency and reduced pollution, improved processes for making high-technology materials, and advances in fire safety for space flight
- Fluid Physics: improved materials processing, safer buildings in earthquake-prone areas and improved stability and performance for power generating stations
- Fundamental Physics: advanced understanding of theories relevant to topics ranging from high-temperature superconductivity to weather prediction to mathematics
- Biotechnology: more effective medicines with reduced side effects and improved knowledge of how tissues grow and develop in the body

8.4.3 Space Sciences

Space Sciences seek to solve the mysteries of the universe, explore the solar system, find planets around other stars, and search for life beyond Earth. Space sciences include studies on solar physics, cosmic physics, astronomy, and astrophysics.

ISS provides scientists with multispectral observations of near and deep space. Prospective subjects for observation include the Sun, planets, comets, asteroids, and the galaxies and nebulae beyond our solar system. Scientists can also expose experiments to atomic oxygen, solar ultraviolet radiation, electron and proton radiation, as well as conduct searches for extraterrestrial anti-matter.

Possible commercial and scientific benefits are a better understanding of solar interaction with Earth's environment and improved ability to predict solar activity.

8.4.4 Earth Sciences

The main goal of Earth science research is to understand the Earth's system and the environmental response to natural and human-induced variations in atmospheric quality, regional and global climate, geologic activity, land use, food production, and ocean and fresh water health.

Through a better understanding of the causes of global changes, policy makers will be able to find solutions to potential large scale environmental problems. Using the information gathered by measurements from space and models constructed from this data, policy makers will be able to make the critical decisions to ensure the long term quality of our environment.

ISS serves as an orbital laboratory supporting a variety of Station-based sensors to further our understanding in Earth sciences. Earth sciences use the Station as a platform for conducting multispectral observations of Earth's land, oceans, and atmosphere. The Station's 51-degree orbital inclination provides a ground-track which covers over 75 percent of the Earth's surface, containing 95 percent of Earth's human population. Various accommodations are provided for Earth sciences research, from externally attached payload sites to a laboratory research window. The crew can reconfigure experimental equipment in response to monitoring cataclysmic events such as earthquakes, volcanic eruptions, and hurricanes.

8.4.5 Commercial Product Development

The commercial product development program was established to increase private sector interest and involvement in commercial space-related activities. The goal of this program is to stimulate interest in promising areas of space research and development with commercial applications. The knowledge gained from this space research is used to create new products and processes, gain competitive economic advantages, create new jobs and improve the quality of life. This program is implemented by Commercial Space Centers. They combine the participation of industry, universities, and other nongovernment organizations to develop specific commercial programs.

8.4.6 Engineering Research and Technology

The Station's microgravity environment provides the opportunity for institutions and industry to exercise tests and demonstrations associated with the advancement of technology and engineering research. Some of the specific areas that will be investigated through the Engineering Research and Technology discipline are: advanced energy storage systems, advanced robotics capabilities, communication systems, electromagnetic propulsion and advanced sensors.

Results from these efforts are planned to contribute toward the development and testing of Space Station upgrades, improved materials and designs for advanced NASA programs and support for U.S. industries in the development of materials and products with commercial potential. Using prototype hardware in space provides an opportunity to evaluate the potential operations, reliability and maintenance characteristics of candidate systems before program commitment.

The Space Station provides an ideal environment for Engineering Research and Technology candidate Payloads to be tested in the pressurized modules of the Station or mounted externally in the vacuum environment of space as the research requires.

8.5 ISS Payloads Components

Payload operations on ISS are supported by a wide variety of programs, equipment and laboratory modules. The following significant payload components are defined

- U.S. Laboratory
- International Standard Payload Rack (ISPR)
- Facility Class Payloads
- EXpedite The PRocessing of Experiments to Space Station (EXPRESS)
- Active Rack Isolation System (ARIS)
- Laboratory Support Equipment (LSE)
- Window Observation Research Facility (WORF)
- Attached Payloads
- Centrifuge Accommodation Module (CAM)
- Japanese Experiment Module (JEM)
- Columbus Orbital Facility (COF)
- Russian Research Modules

8.5.1 U.S. Laboratory

The U.S. Laboratory is a pressurized module designed to accommodate pressurized payloads (see Figure 8-1). This module has a capacity of 24 rack locations. Payload racks will occupy 13 locations especially designed to support experiments (see Figure 8-2). Each of the payload rack locations provides the standard ISS Payload rack support structure and interfaces for Payload rack installation and retention. At each of the Payload rack locations in the U.S. Laboratory, there are interfaces for ISS-provided utilities and resources to which the Payload can be connected. The ISS utilities available to each Payload rack location are routed to rack utility interface panels located at the base of the rack locations. The utilities available at the respective locations are

- Electrical power
- Command and data interfaces
- Internal Thermal Control System (TCS)
- Nitrogen gas

- Video signal connection
- Vacuum resource and exhaust

The rack utility interface panels also include a connection for the Fire Detection System (FDS) and the rack maintenance switch circuits.

Utility Outlet Panels (UOPs) within the U.S. Lab are specifically designed for payloads which provide connectivity and electrical power for the ISS Portable Computer System (PCS) and ISS Ethernet connectivity.

Payload racks installed in the U.S. Laboratory will be transported to the ISS by the shuttle as cargo integrated into the Mini-Pessurized Logistics Module (MPLM) and transferred to the U.S. Laboratory during joint shuttle/Station operations.

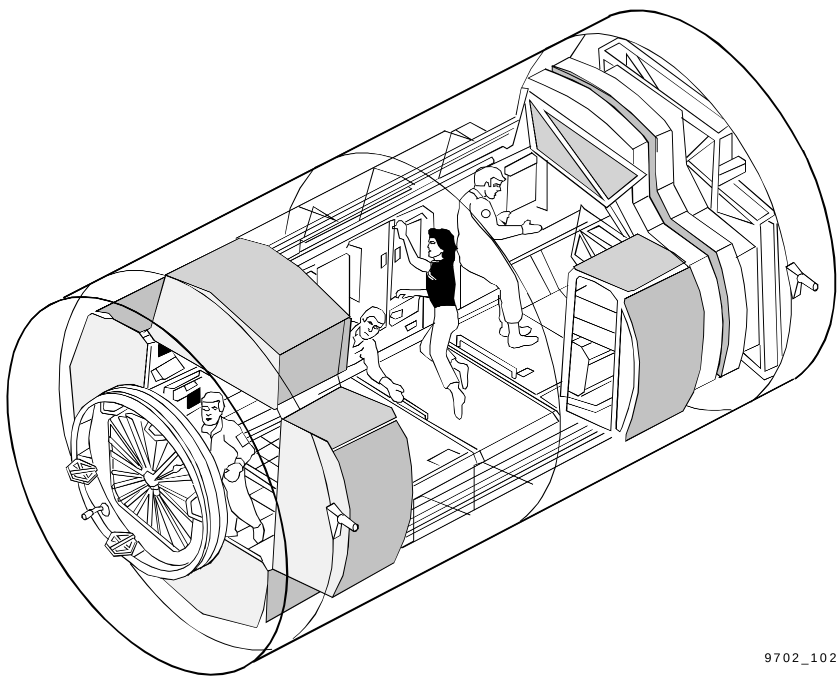

Figure 8-1. U.S. laboratory module

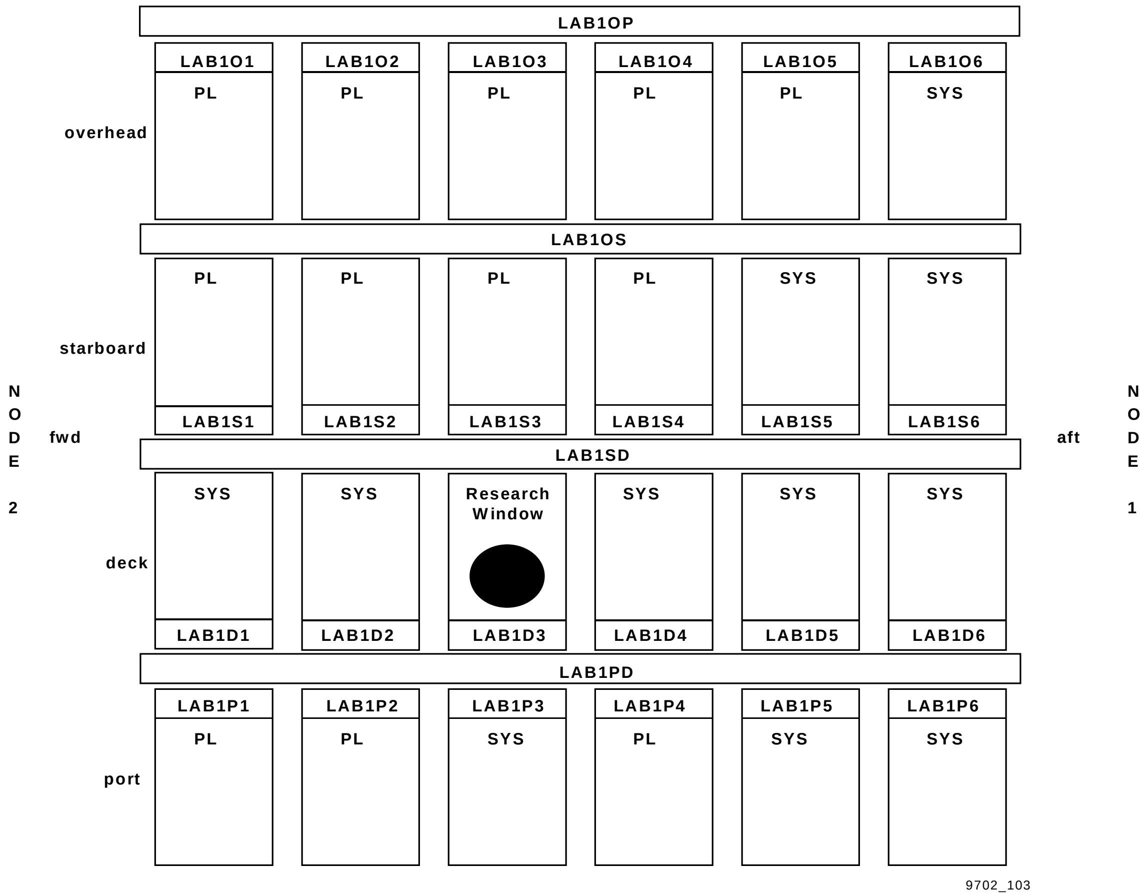

Figure 8-2. U.S. Lab topology

8.5.2 International Standard Payload Rack

The International Standard Payload Rack (ISPR) (Figure 8-3) is designated as the standard payload equipment interface to the ISS for U.S. pressurized payloads. The ISPR provides the basic housing and support structure for the mounting of payload hardware and equipment installed in the ISS Payload rack locations in the U.S. Lab and International Partner (IP) modules.

The ISPR consists of a laminated composite outer shell that is structurally reinforced by vertical and horizontal aluminum posts.

The ISPR is equipped with an Avionics Air Assembly (AAA) to support the Fire Detection System (FDS) and can be outfitted with umbilicals to interface with the U.S. Laboratory Rack Utility Interface panels. Through these umbilicals, the payload has access to the standard utilities.

Individual payloads can be designed to occupy a partial rack volume, a full rack volume or multiple racks.

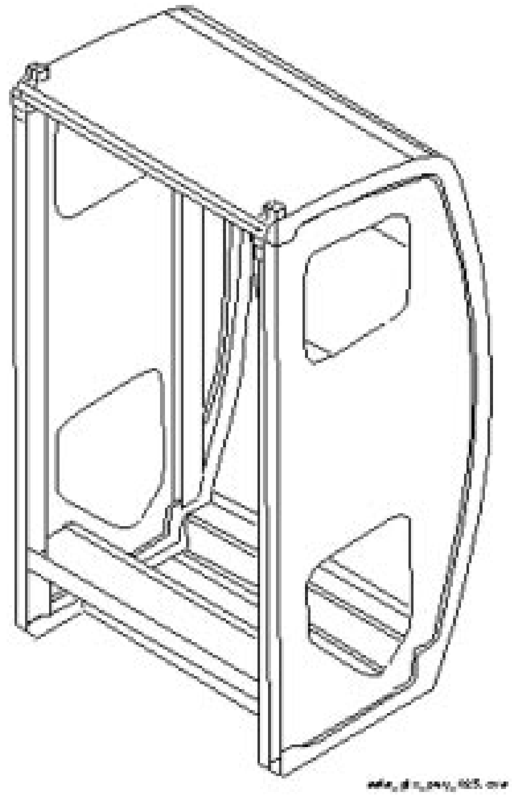

Figure 8-3. International Standard Payload Rack

8.5.3 Facility Class Payloads

A Facility Class Payload is a long-term or permanent Station resident that provides services and accommodations for experiments in a particular science discipline. These facilities are designed to allow easy changeout of experiments by the crew and to accommodate varied experiments. The services provided to the experiments include physical support interfaces, command and control, data/video handling and control/distribution of Station resources.

Some of the U.S.-developed facility class payloads are listed below

- Human Research Facility
- Fluids and Combustion Facility
- Biotechnology Facility
- X-ray Crystallography Facility
- Material Science Facility

Details on the design, operations and interfaces of facility class payloads are presented in the Payload Operations and Interfaces Training Manual.

8.5.4 EXpedite the PRocessing of Experiments to Space Station

The International Space Station (ISS) program has established the EXpedite the PRocessing of Experiments to Space Station (EXPRESS) program in order to reduce the long lead time traditionally required for planning and integrating a space experiment. EXPRESS provides payload accommodations which allow quick, simple integration by using standardized hardware interfaces and a streamlined integration approach. The EXPRESS program consists of two separate systems: the EXPRESS rack for pressurized payloads and the EXPRESS pallet for attached payloads. (The EXPRESS pallet is discussed in Section 8.5.8 Attached Payloads.)

The EXPRESS rack provides accommodations for payloads that do not require the entire volume of an International Standard Payload Rack (ISPR), including the new Station payloads as well as existing payloads that have flown in the shuttle middeck, Spacelab, Spacehab or Mir. The rack provides physical interfaces for payloads contained in Standard Interface Rack (SIR) drawers, Middeck Lockers (MDLs) or their equivalents. The rack also provides the following standard services: command and control, data/video handling, 28 V dc power, avionics air and water cooling, vacuum exhaust and gaseous nitrogen. The rack, illustrated in Figure 8-4, an 8/2 EXPRESS Rack because it can accommodate eight middeck lockers and two SIR drawers.

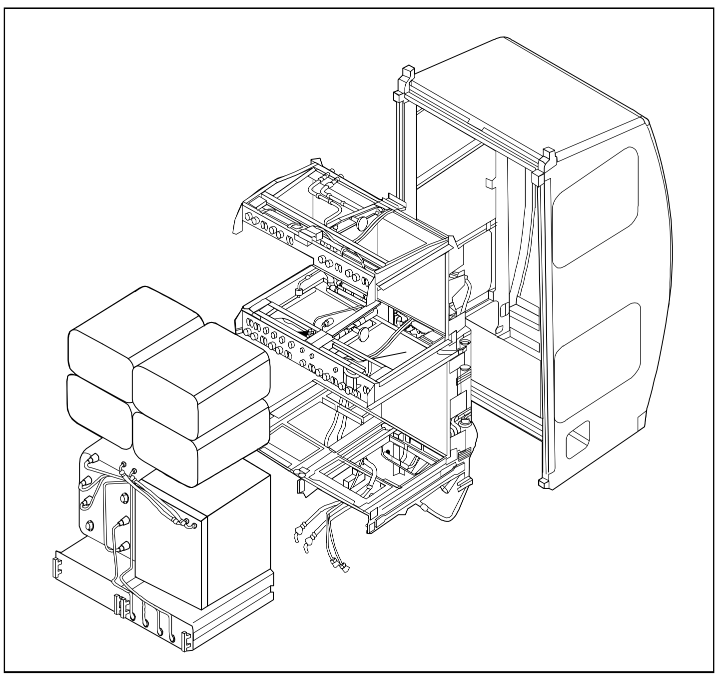

Figure 8-4. 8/2 EXPRESS rack

The figure shows the rack separated into three sections: the basic ISPR, the EXPRESS hardware and EXPRESS payload containers. The EXPRESS hardware consists of the physical interfaces for accommodating the MDLs and SIR drawers and the supporting equipment, including an Avionics Air Assembly (AAA), power conversion/control equipment, and a Rack Interface Controller (RIC) for payload command/control and data/video handling. The figure shows four single MDLs, two double MDL-equivalent containers and two SIR drawers.

8.5.5 Active Rack Isolation System

Figure 8-5 shows the Active Rack Isolation System (ARIS) which is a Payload support system intended to satisfy strict payload microgravity requirements. ARIS is designed to reduce vibratory accelerations taking place at a specific ISPR.

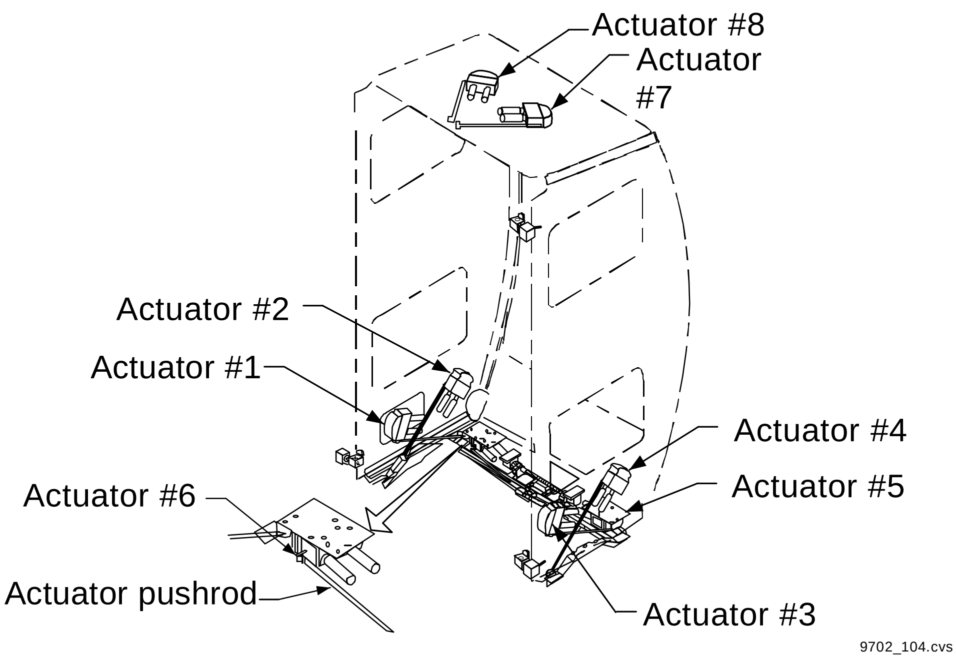

Figure 8-5. Active Rack Isolation System

An ARIS-equipped rack is suspended by eight actuators pushrods. Vibrations are sensed by three rack-mounted accelerometers. This measurement information is used to send control signals to specific actuators to attenuate disturbances. The maximum disturbance magnitude controlled by ARIS is 1000 micro-G.

8.5.6 Laboratory Support Equipment

Laboratory Support Equipment (LSE) are devices that are shared on a noninterference basis by multiple research users. LSE vary in size and complexity from a simple thermometer, to a full-size ISPR containing a refrigerator/freezer (Figure 8-6).

In general, LSE fall into one of the following categories

- Refrigerators and cryogenic freezers
- Microscopes
- Tools
- Instruments
- Cameras

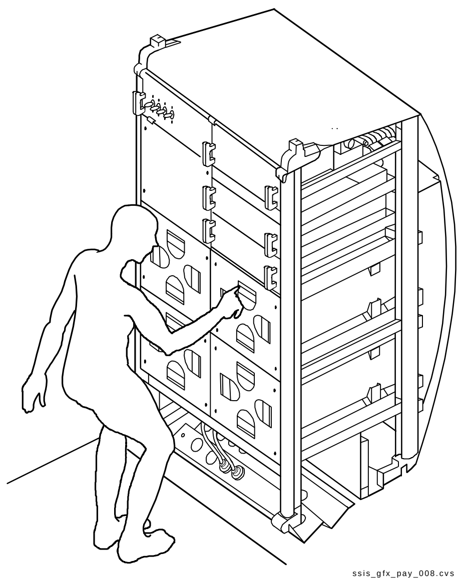

Figure 8-6. Refrigerator/freezer

8.5.7 Window Observation Research Facility

The Window Observation Research Facility (Figure 8-7) will primarily be used for Earth observation through the nadir-facing window in the U.S. Lab. During the assembly phase one or two cameras can be operated simultaneously, whereas, at Assembly Complete multiple cameras may be operated at the window location, due to advanced support interfaces. Since the Window may be used after the delivery of the U.S. Lab, this particular design shows one of the options for early science return on Space Station.

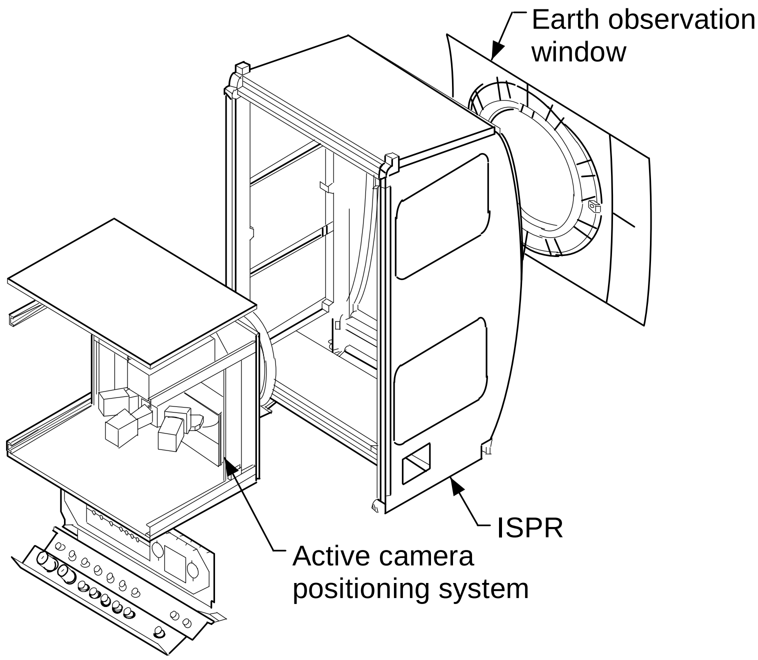

Figure 8-7. Window Observation Research Facility

8.5.8 Attached Payloads

Attached Payloads (Figure 8-8) are located outside of the pressurized volume of the Space Station on the truss or the Japanese Experiment Module Exposed Facility (JEM EF). Four locations on the S3 truss segment, two locations on the P3 truss segment and ten locations on the JEM EF house attached payloads. Five of the locations on the JEM EF are allocated for National Space and Development Agency of Japan (NASDA) payloads and five for NASA payloads.

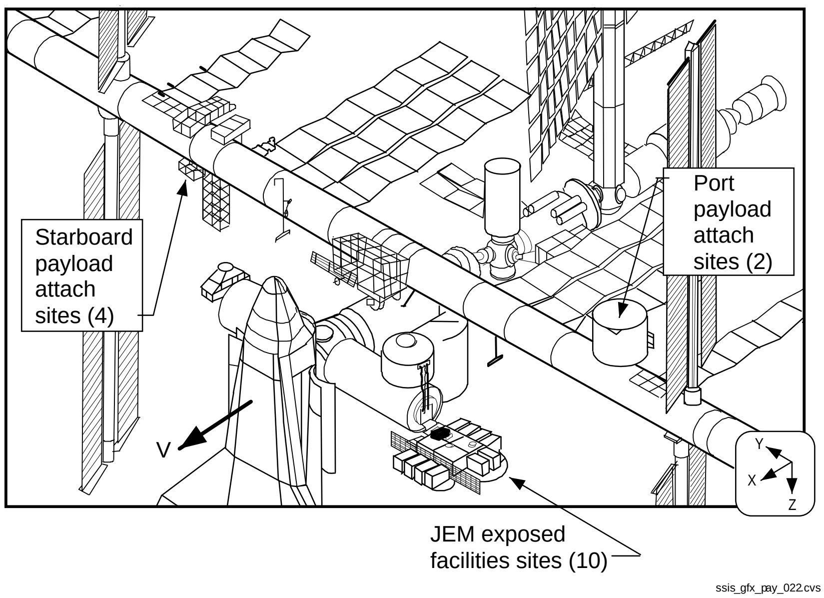

Figure 8-8. Attached payload sites

The EXpedite the PRocessing of Experiments to Space Station (EXPRESS) Program also applies to attached payloads. The EXPRESS Pallet (Figure 8-9) can be located at any site on the truss segment, has six robotically replaceable adapters for payloads or payload complements.

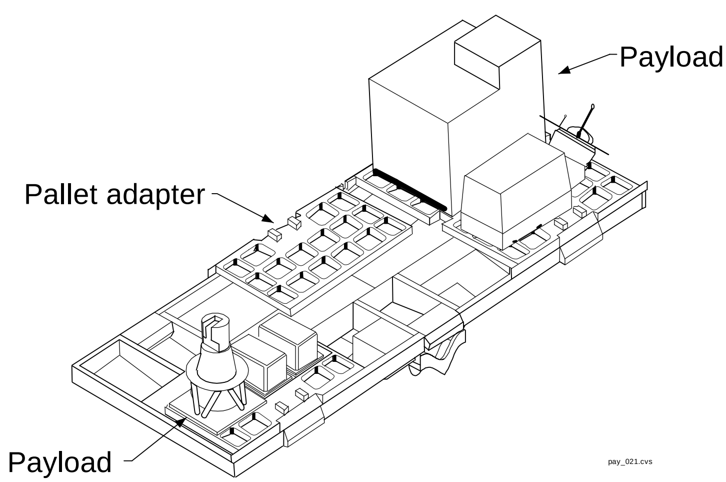

Figure 8-9. Example of an EXPRESS pallet with payloads

Attached payloads may use the Station power, command and data handling system and video. The Japanese Experiment Module Exposed Facility has active cooling. The crew will interface using robotics for installation and removal of the attached payloads, with no nominal EVA operations anticipated.

8.5.9 Centrifuge Accommodation Module

The Centrifuge Accommodation Module (CAM) (Figure 8-10) is a research facility especially designed to study the effects of selected gravity levels (0.01g-2g) on the structure and function of plants and animals, as well as to test potential countermeasures for the changes observed in microgravity. This module accommodates a 2.5-meter diameter centrifuge rotor, two habitat holding unit racks, plant and animal habitats, and a glovebox. This module is being constructed by NASDA under NASA contract. It supports extended duration investigations, including multigeneration studies, and the opportunity to collect biological samples on-orbit in the microgravity environment. The CAM provides the same interface to ISS resources as the U.S. Lab.

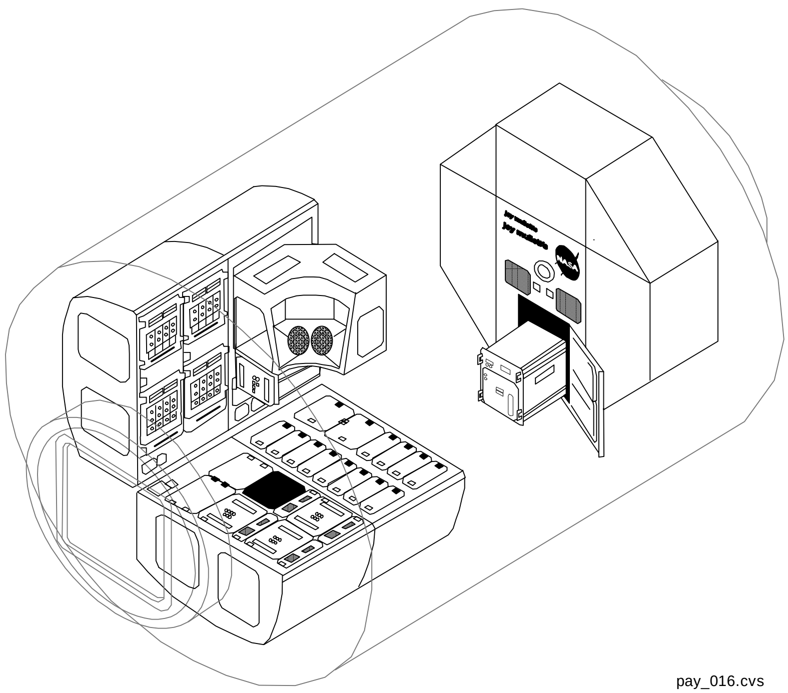

Figure 8-10. Centrifuge accommodation module

8.5.10 Japanese Experiment Module

The Japanese Experiment Module (JEM) (Figure 8-11), is provided by the National Space Development Agency of Japan (NASDA). The JEM Pressurized Module (JEM PM) has ten locations for International Standard Payload Racks (ISPRs). Five of the payload locations are allocated to NASDA payloads and five to NASA payloads. The JEM PM provides the same interfaces to the Station resources as the U.S. Lab. In addition, the JEM PM has carbon dioxide, argon and helium gases and provides an airlock for changeout of samples or payloads on the exposed facility.

The Japanese Experiment Module Exposed Facility (JEM EF) has five locations for NASDA attached payloads and five for NASA attached payloads. The JEM EF has a unique interface for active cooling of the attached payloads. In addition, the Japanese Experiment Module includes the Experiment Logistics Module - Exposed Section (ELM ES) and the Experiment Logistics Module - Pressurized Section (ELM PS). The Experiment Logistics Module - Exposed Section (ELM ES) will be used for initial transport of attached payloads to the JEM EF.

The Experiment Logistics Module - Pressurized Section (ELM PS) will be used for initial transport of payload and logistics racks to the JEM PM.

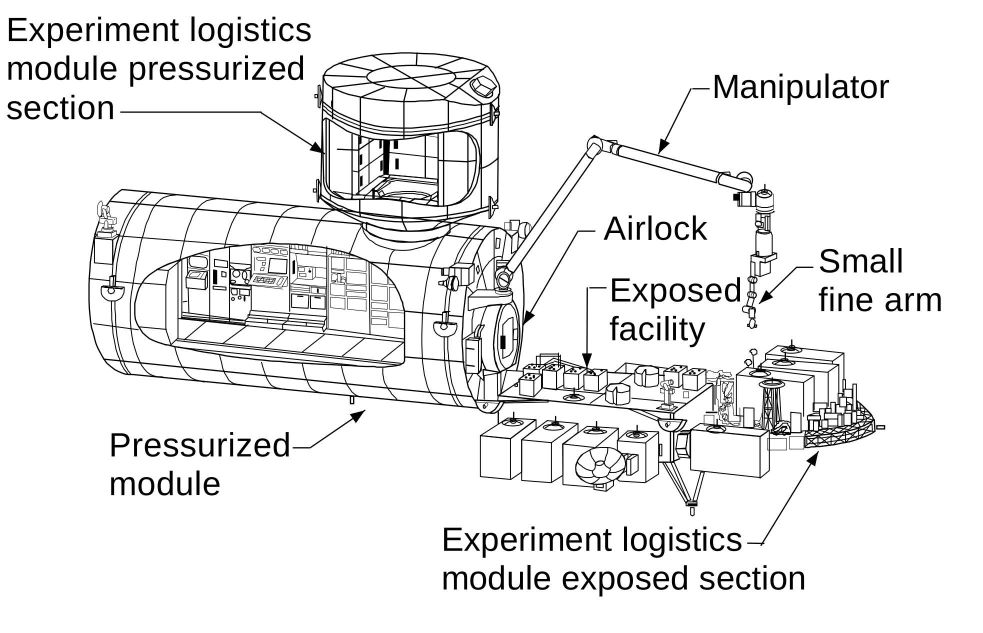

Figure 8-11. Japanese Experiment Module

8.5.11 Columbus Orbital Facility

The Columbus Orbital Facility (COF) called the Attached Pressurized Module (APM) (Figure 8-12) is the major European Space Agency (ESA) contribution to the ISS. The COF is used primarily for research and experimentation in microgravity conditions for material sciences, fluid physics, and life science. The COF accommodates ten ISPR locations: five allocated to NASA utilization and five are to ESA utilization. The COF provides the same interfaces to ISS resources as the U.S. Lab.

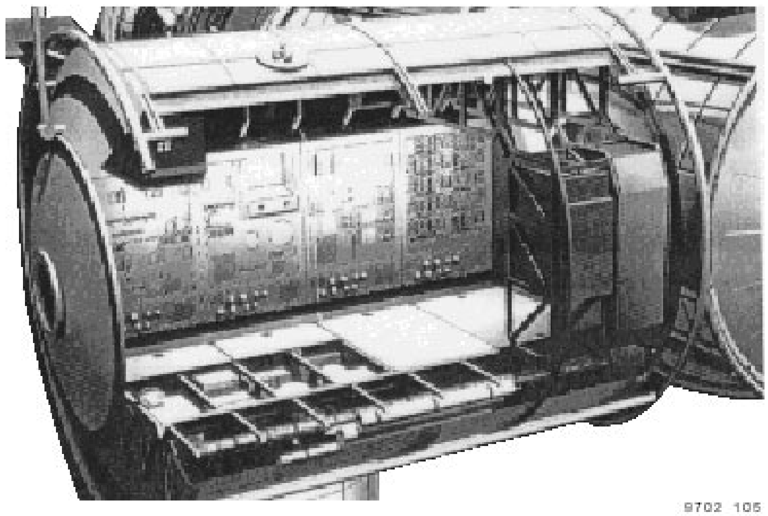

Figure 8-12. Columbus Orbital Facility

8.5.12 Russian Research Modules

The Russian Space Agency (RSA) will provide two research modules (Figure 8-13). These modules will be attached to the ISS later in the assembly sequence and are currently in the conceptual design phase. The total capacity for payloads has not been defined. Russian Research Modules may include different payload support structures than the International Standard Payload Racks (ISPR).

Russian Research Modules will accommodate experiments in different disciplines including Earth and Space Sciences, Fundamental Biology, Human Life Sciences, Microgravity Sciences and Advanced Technology.

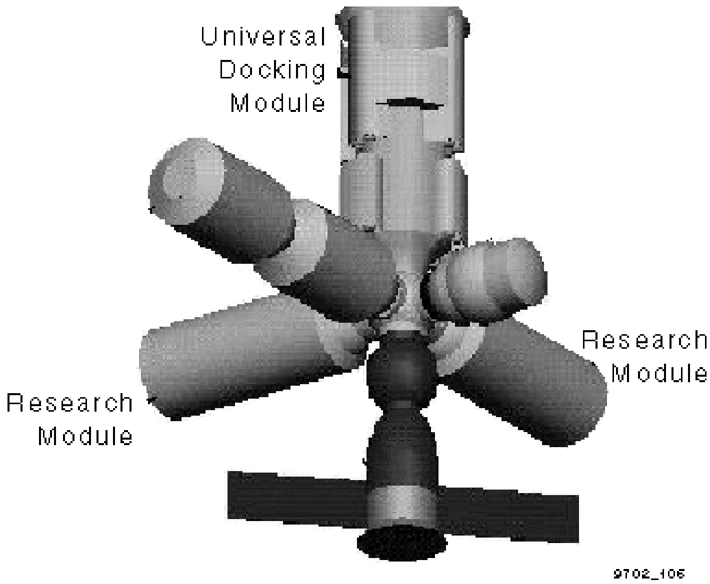

Figure 8-13. Research modules

8.6 Summary

The purpose of the ISS is to provide a permanent manned platform for conducting research in space. The principal advantages for conducting research on the ISS are the access to the microgravity environment, the unique vantage point provided by low Earth orbit, and the extended periods of time to perform the experiments.

The types of research planned for ISS are summarized below

- **Life Sciences:** Study how plants and animals adjust to the absence of gravity. Conduct research which could aid in the treatments and prevention of numerous diseases and medical conditions experienced on Earth.
- **Microgravity Sciences:** Study processes which are obscured by gravity on Earth and test physical theories at levels of accuracy that are impossible on Earth. Specific disciplines of

microgravity science which will be studied aboard ISS include: materials science, combustion science, fluid physics, fundamental physics, and biotechnology.

- **Space Sciences:** Seek to solve the mysteries of the universe, explore the solar system, find planets around other stars, and search for life beyond Earth. The focus of space science includes studies on solar physics, cosmic physics, astronomy, and astrophysics.
- **Earth Sciences:** Study the Earth's system and the environmental response to natural and human-induced variations in atmospheric quality, regional and global climate, geologic activity, land use and food production, and ocean and fresh water health.
- **Commercial Product Development:** Increase private sector interest and involvement in commercial space-related activities and stimulate advances in promising areas of space research and development with commercial applications.
- **Engineering Research and Technology:** Provide the opportunity for academic institutions and industry to create "test-beds" and run experiments associated with the advancement of technology and engineering research. Some of the specific areas that will be investigated are: advanced energy storage systems, advanced robotics capabilities, communication systems, electromagnetic propulsion and advanced sensors.

The following payload components are provided to support research operations on ISS

- **U.S. Laboratory Module:** NASA contribution to the ISS laboratory complement that accommodates 13 payload racks.
- **International Standard Payload Rack (ISPR):** Provides the basic housing and support structure for the mounting of payload hardware and equipment that are to be installed in the U.S. Lab and IP modules.
- **Facility Class Payloads:** A long term or permanent Station resident that provides services and accommodations for experiments in a particular science discipline.
- **EXpedite the PRocessing of Experiments to Space Station (EXPRESS):** Provides payload accommodations which allow quick, simple integration by using standardized hardware interfaces and a streamlined integration approach.
- **Active Rack Isolation System (ARIS):** Payload support system intended to satisfy strict microgravity requirements by attenuating vibratory accelerations at a specific rack.
- **Laboratory Support Equipment (LSE):** Devices that are shared on a noninterference basis by multiple research users.
- **Window Observational Research Facility (WORF):** The facility supporting Earth observations at the nadir-facing research window in the U.S. Lab.
- **Attached Payloads:** Payloads located outside of the pressurized volume of the Space Station on the truss or the Japanese Experiment Module Exposed Facility (JEM EF).

- **Centrifuge Accommodation Module (CAM):** Laboratory module built by NASDA under NASA contract that accommodates a variable speed centrifuge and plant and animal habitats.
- **Japanese Experiment Module (JEM):** NASDA contribution to the ISS laboratory complement that accommodates 10 payload racks and 10 attached payload sites.
- **Columbus Orbital Facility (COF):** ESA contribution to the ISS laboratory complement that accommodates 10 payload racks.
- **Russian Research Modules:** RSA contribution to the ISS laboratory complement which is currently in the conceptual design phase.

Questions

1. Which one of the following ISS types of research includes Fluid Physics?

    (a) Biotechnology

    (b) Life Sciences

    (c) Microgravity Sciences

    (d) Space Sciences

2. Which one of the following ISS types of research is primarily concerned with environmental processes?

    (a) Materials Science

    (b) Combustion Science

    (c) Earth Sciences

3. Which of the following best characterizes an International Standard Payload Rack (ISPR)?

    (a) Long-term/permanent Station resident that provides services to a specific type of research.

    (b) Basic support structure and outer shell for housing payload hardware.

    (c) Devices that are shared on a noninterference basis by multiple users.

    (d) Supports a simple, short integration process and provides standardized interfaces or experiments.

4. Which of the following best characterizes a Facility Class Payload?

    (a) Long-term/permanent Station resident that provides services to a specific type of research.

    (b) Basic support structure and outer shell for housing payload hardware.

    (c) Devices that are shared on a noninterference basis by multiple users.

    (d) Supports a simple, short integration process and provides standardized interfaces or experiments.